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Residential Solar Mass Wall Analysis for Canada

INTRODUCTION

Passive solar heating offers great promise for reducing the use of conventional heating fuels in Canadian houses.

Direct gain is the most common form of passive solar heating. Sunlight enters through south-facing windows, where it heats the room interior and is stored in the building fabric to be released later. This study explores the performance of another type of passive solar heating system—the mass wall. Mass walls hold the promise of being able to provide passive solar heating in situations in which direct gain is not suitable.

A mass-wall solar heating system places a 200 to 300 mm (8 to 12 in.) thick concrete wall behind a southward-facing glazing.

The wall surface behind the glazing is painted a dark colour, usually black, or covered with a selectively coated metal foil. Sunlight passing through the glazing falls on the outside face of the wall, heating it up. The heat is conducted through the concrete wall and transferred to the room behind the wall by radiation and convection (see figure 1.)

A variation of this type of passive solar system, in which high and low vents are located through the concrete wall, is referred to as a Trombe wall after the French architect who first proposed and constructed this type of system (see figure 2.)

In a Trombe wall, heat is transferred both through the wall by conduction and by the movement of air due to natural convection. Air located between the glazing and the outer face of the concrete wall is heated and rises, entering the room through the upper vent to be replaced by cooler room air that enters the Trombe wall through the lower vent at the base of the wall. The vents are closed at night to prevent cooling.

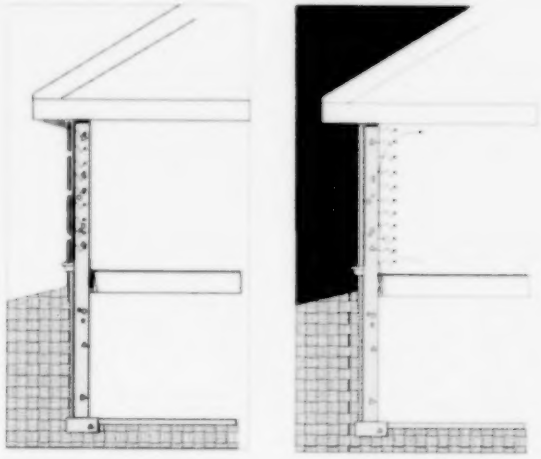

Figure 1 Mass wall day and night

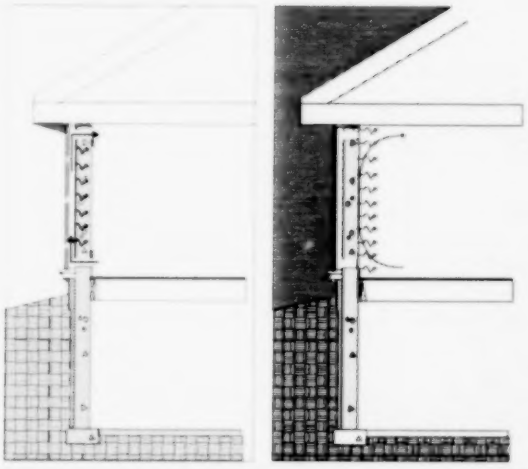

Figure 2 Trombe wall day and night

Canada

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HOME TO CANADIANS

This research investigated mass walls as an alternative to direct-gain passive solar heating. In theory, solar mass walls can:

- Provide designers and homeowners with a wider range of options that can be used to produce a solar-heated home that meets their specific needs.
- Provide an alternative where direct gain or direct gain alone is not the best solution. An example is a situation in which either privacy, or noise, or sunlight exposure (higher temperature, UV degradation of furniture, fabrics and artwork), or all, preclude using large, glazed, south-facing areas.
- Provide solar gains to spaces in which temperature swings ought to be minimized.
- Provide solar gains to spaces, such as home offices, in which glare has to be minimized or eliminated.
- Provide solar gains to spaces in which lighting needs to be closely controlled or where daylighting may not be desirable, such as in home theatres.
- Provide solar gains to spaces largely used at night, such as bedrooms.

However, the extent to which solar mass walls can deliver these benefits in Canadian housing has not been fully explored. Therefore, CMHC commissioned a research project to assess, via computer simulations, the energy performance of two solar mass wall assemblies.

PROJECT METHODOLOGY

The study consisted of three tasks:

Task 1

The first task was developing representative sample homes that could be used in computer modelling.

To do this, the researchers used updated residential thermal archetypes for six locations (Vancouver, Edmonton, Winnipeg, Toronto, Montréal and Halifax) based on earlier work carried out by Natural Resources Canada, combined with current EnerGuide (EGH) database. These houses were then modified using *HOT2000* [1] to achieve R-2000 and Advanced House levels of performance, resulting in a total of 18 thermal archetypes (six conventional, six R-2000 and six advanced)

South window sizing was determined by the use of the *Overheating Design Checker* software that is part of the CMHC publication *Tap the Sun* [2]. The houses had the following ratios of south window area-to-floor area:

- Conventional (current code) home—4 to 5 per cent
- R-2000—3 to 4 per cent
- Advanced House—2.5 to 3 per cent

Task 2

The second task was the input of the archetype data into *Suncode*, a PC version of *SERI-RES* or *SUNREL* software, to run baseline hourly performance simulations. *Suncode* is an hourly simulation model that, unlike most other thermal simulation software, has the capability to model mass wall and Trombe wall passive solar heating systems.

Task 3

Running hourly mass wall performance simulations was the third task for the researchers. Sensitivity runs were performed in which a portion of the south wall area of each of the baseline archetypes was replaced with a mass wall of varying characteristics. The objectives of these runs were to determine:

- the predicted hourly temperatures on the inside surface of the mass wall for a typical clear winter day;
- the predicted hourly temperatures of the air space between wall and glazing for a typical clear winter day;
- the predicted hourly temperatures on the inside surface of the mass wall for a typical cloudy winter day;
- the predicted hourly temperatures on the inside surface of the mass wall for a typical sunny summer day;
- the annual useful energy collected, by system (referenced to base cases).

One of the design goals was to select a wall thickness that ensured that heat gains to the space were delayed until the overnight hours—so as to not coincide with direct gain solar or internal heat gains. For this reason, most runs assumed the mass walls were not vented to the interior, which would have increased daytime solar heat gains.

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1 Natural Resources Canada software used to determine how much energy a home will use and to ensure that this level is at or below the energy target set by the R-2000 Standard.

2 Canada Mortgage and Housing Corporation, *Tap The Sun: Passive Solar Techniques and Home Designs*, 2006

Reduction in Loads:

	Area m^2	Thick mm	Sfc.	Glazing	Vancouver MJ/m^2y	Edmonton MJ/m^2y	Winnipeg MJ/m^2y	Toronto MJ/m^2y	Montréal MJ/m^2y	Halifax MJ/m^2y
Conventional	15.25	300	Low-e	T_2 low-e arg	178.8	147.1	133.3	101.9	94.4	126.8
R2000	15.25	300	Low-e	T_2 low-e arg	112.3	65.8	99.0	81.4	5.6	63.0
Advanced	15.25	300	Low-e	T_2 low-e arg	69.4	35.7	14.0	34.0	-2.0	40.5

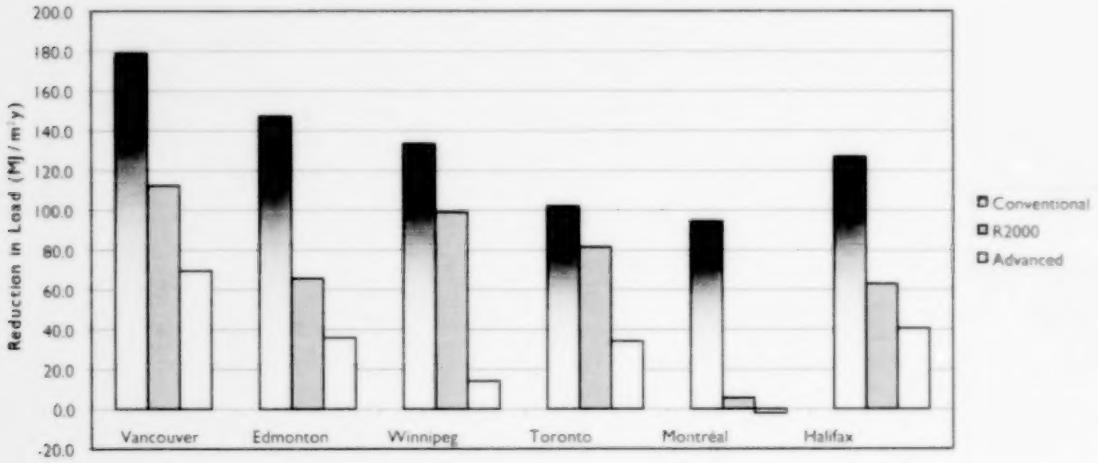

Figure 3 The reduction in heating loads for the three thermal archetypes by location

High-performance mass walls were tried for all levels of house insulation and locations. They consisted of a 300 mm (12 in.) thick concrete wall with a selective surface coating (Sfc.) placed on the outside face of the wall and a high-performance glazing.

A selective surface, typically used in solar collectors, is a metal surface that is a good absorber of solar radiation while at the same time is a very poor emitter of infrared radiation. Selective surfaces are available as metal foils that can be applied to a substrate. These characteristics increase the ability of the wall to collect solar radiation while reducing heat losses to the outside environment. The high-performance glazings consisted of:

- Double-glass panes with one hard coat, low-e coating; or
- A triple-glazing with glass on the inside and outside and a plastic film with a soft coat, low-e coating suspended between, or
- A triple-glass pane glazing with two hard, low-e coatings, or
- A translucent insulation in which a transparent honeycomb is suspended between two layers of glass.

These glazing systems have a solar heat gain (SHG) of about 0.52, and RSI values between 0.9 and 1.1

RESULTS

As Figure 3 shows, the largest load reductions (biggest contribution to space heating by the mass wall) were in Vancouver, because of lower mass-wall heat losses due to milder outside temperatures.

Reduction in loads is strongly dependent on the level of conservation of the house. The conventional house has a longer "heating season" and much of the reduction in load is in the fall and spring when there is more sunlight and higher outside temperatures (lower losses from the mass wall).

The apparently anomalous results for R-2000 and advanced houses in Montréal cannot be explained, even after re-running the simulations and a detailed analysis of the results. Both nearby Toronto and Montréal show net losses from November through February, however, in Montréal, the spring and fall gains are insufficient to compensate.

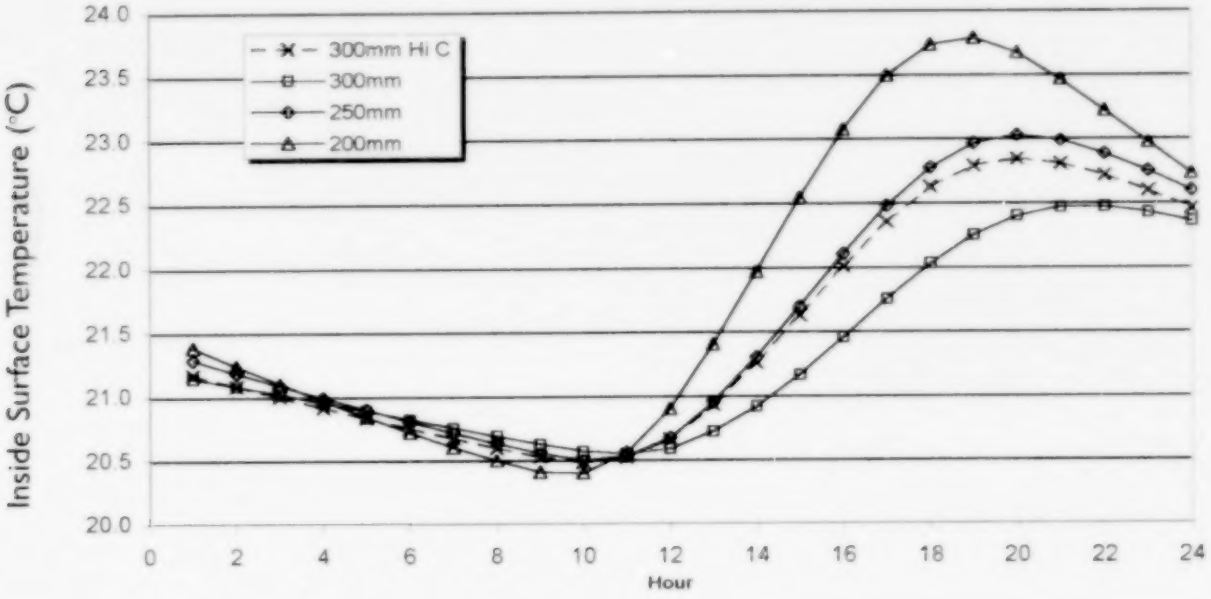

Figure 4 Sample of inside surface temperatures (degree Celsius) for an R-2000 house in Vancouver on a spring day

In addition to calculating the reduction in heating load due to the mass wall, *Suncode* also provided output showing temperatures at various locations throughout the wall.

Figure 4 shows a sample of the inside surface temperatures over 24 hours for various thicknesses and conductivity (Hi C = High Conductivity) of a 15.25m² (163.61 sq. ft.) mass wall in an R-2000 house in Vancouver on a spring day.

All the walls simulated have a selective surface on the face of the concrete wall and a triple-glazed unit using two low-e coatings and argon gas fill.

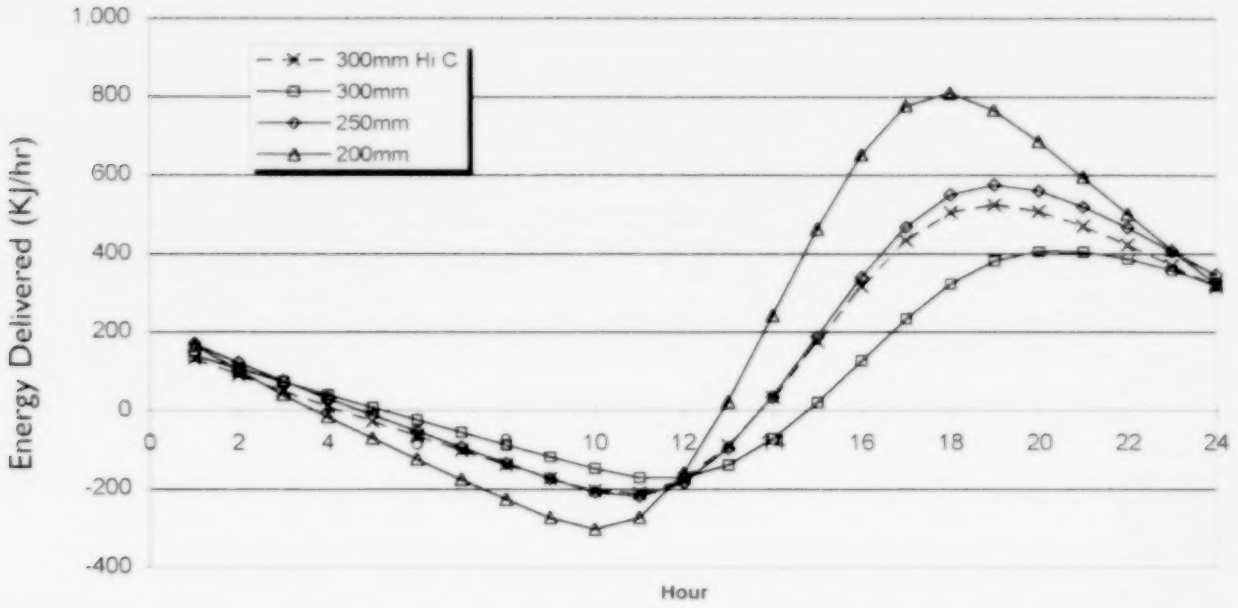

Figure 5 Energy delivered (kJ/hr) to the inside of the Vancouver house on a typical clear winter day

Figure 5 shows—for the same house, mass wall types and location—the amount of energy delivered to the inside space on a typical clear winter day with outside temperatures ranging from -3.3 to 3.3°C (26.06 to 37.94°F). The thinnest wall delivers the greatest amount of energy.

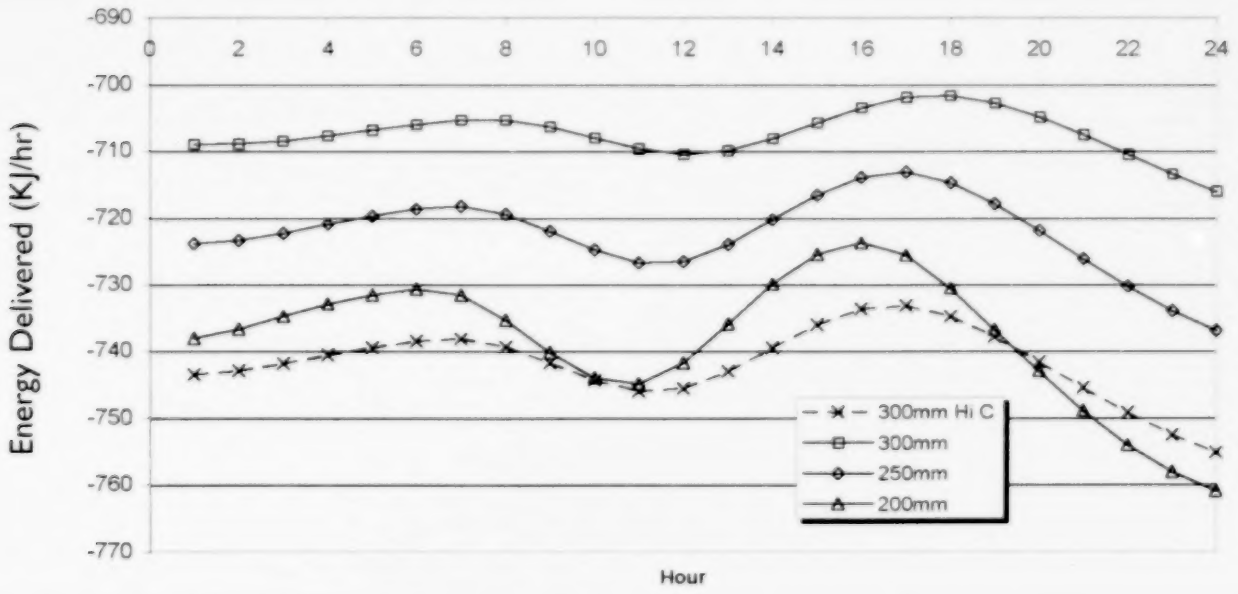

Figure 6 Energy delivered (kJ/hr) to the inside of the Vancouver house on a typical cloudy winter day

Figure 6 shows the amount of energy delivered to the inside space of the same house, mass wall types and location on a typical cloudy winter day with outside temperatures ranging from 0.6 to 4.4°C (33.08 to 39.92°F). The thinnest wall loses the greatest amount of energy.

CONCLUSIONS

Mass or Trombe (vented) walls replacing well-insulated south walls yield relatively small reductions in space heating loads (zero to about 180 MJ/m^2 of mass wall, depending on configuration and location), even with selective surfaced walls and high-performance glazings. The milder west coast climate yielded the greatest reduction in space heating loads.

Replacement of south glazings with mass or Trombe (vented) walls can reduce space heating loads by about 0.5 GJ/m^2/y in an R-2000 house and close to 1.0 GJ/m^{2}y in a conventional house— one per cent reduction in space heating loads for both the R-2000 house and the conventional house.

Venting the mass wall has very little effect on space heating load reduction (three to five per cent more) relative to an unvented mass wall. More daytime load is offset by less evening load. Air temperatures in front of the mass wall are reduced with venting. If combined with direct gain there is a greater potential for overheating of the room behind the mass wall.

A 300 mm thick wall of normal conductivity will provide peak heating around 9 p.m., while a 200 mm thick wall will peak around 7 p.m. A higher conductivity wall has an effect similar to reducing its thickness. Energy performance suffers slightly with decreased thickness and/or higher conductivity.

Black-surfaced walls with double-glazed, low-e glazings are net energy losers in better insulated houses in the colder parts of the country.

In most cases, room air temperatures were similar or lower with the mass walls than for the base cases.

Based on the best current solar energy absorber and glazing technology, mass walls do not appear to be a feasible option for space heating in Canada.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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